Preface

The work reported in this thesis relates to driven systems, where the conventional wisdom of equilibrium thermodynamics breaks down There are no general methods to tackle such problems, and each problem has to be treated in its own right We have, in the main, resorted to a stochastic description of these problems, through generalized Langevin equations, Master equations, and stochastic lattice models A brief survey follows

1 Shear Induced Melting and Reentrance in Colloidal Suspensions

The phenomenon of shear induced melting was observed in 1981 by Ackerson and Clark while performing light scattering experiments on charge stabilized colloidal suspensions These suspensions can form a crystalline state in equilibrium that Bragg scatter visible laser light and have a shear modulus of the order of a few hundred dynes/sq cm The experiments found that the Bragg peaks disappeared at a critical shear rate, which went roughly linearly with $n - n_c$, where n is the ionic impurity concentration (which acts like a temperature) and n_c its value at the equilibrium phase boundary Subsequent Molecular dynamics not only found a similar melting transition but also a *reentrance* to the crystalline phase at high shear We set up and solved a simple two variable model for these nonequilibrium phase transitions, introducing a plausible criterion for identifying the stable phase in a steady state problem We used a single order parameter for the closest shell of Bragg peaks and an angle-like variable to denote the state of shear of the crystal We wrote down generalized Langevin equations of motion for these mean field variables, and obtained the steady state probability distribution for the order parameter, which we used to determine the stable phase Our phase diagram reproduced all the qualitative features of the experiments and simulations the linear takeoff at small $n - n_c$, reentrance, and the absence of any transition at small enough n

2 Noise Induced Drift in Symmetric Potentials

Ratchetlike potentials in combination with coloured noise or driving have been shown to exhibit current carrying steady states These one-particle models have been proposed as a paradigm for understanding drift-like motion ($l \propto t$ as opposed to $l \propto \sqrt{t}$) of motor proteins in cells We explored an alternative mechanism for drift motion, namely a symmetric potential and a skew, white noise In agreement with intuition, we found both analytically and numerically, that there is a current in the steady state of such a model, which goes to zero for weak as well as strong noise amplitude/potential We also found a reversal of current for noises that had odd moments beyond the third From a similar mechanism, we showed that even a Gaussian white noise in a ratchet potential can induce currents if the amplitude of the noise kicks is not much smaller than the period of the potential We constructed a Maxwell demon to illustrate the ideas and suggested an experiment involving a colloidal particle in a fluidized bed and a laser field to test our results experimentally

3 Stability of Sedimenting Colloidal Crystals

We have studied the problem of a steadily sedimenting colloidal crystal as a physical realization of a many body system under a constant external field, whose mobility is a function of the local strain (compression, shear, tilt) Extending the ideas of Crowley, who showed by dropping an array of steel balls in turpentine and from elementary hydrodynamics, that hydrodynamic interactions between sedimenting particles can destabilize a regular array, we have set up equations of motion for the displacement field of an *elastic* crystal in a fluidized bed We have shown that the restoring forces cannot stabilize the crystal at long wavelength within a linear theory We have therefore included nonlinearities in the continuum equations of motion, and looked for steady states within a mean field approach We have then reduced the problem to a more tractable one in one spatial dimension, but with two displacement fields one along and the other perpendicular to the sedimentation direction To study the unstable system with fluctuation effects, we have set up a lattice model with two conserved fields concentration and tilt A detailed study of this model has shown that there is a continuous nonequilibrium phase transition as the Peclet number is increased The low driving crystalline phase appears as a homogeneous state in terms of the lattice model, and the high driving clumped and buckled crystal goes over to a phase separated state Thus the crystal been shown to be stabilized by nonlinear effects at low driving, finally giving way to the instability and forming clumps or breaking up into crystallites at a critical Peclet number The stable version of the continuum model, which corresponds to the low Peclet number regime where the crystal is stable, has been studied analytically, and we have found an exact Fluctuation Dissipation theorem for one set of parameter values, and a decoupling into two KPZ-like equations for another

4 Freezing of Sedimenting Colloids

The mobility of a collection of particles moving under a constant external field (like gravity) depends on the local concentration The effect of this concentration dependence of mobility on the liquid solid transition has been studied within a generalized Langevin equation framework The equations of the density field acquire a Burgers KPZ like nonlinearity, which affects the correlations in the liquid and hence the phase boundary We have calculated the lowest order correction to the three point vertex and the structure factor of a liquid near the transition Using these, we have looked for steady states of the Fokker Planck equation, and predicted a quadratic shift in the phase boundary towards the liquid side